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Stimulus control in pigeons following varied lengths of discrimination training with compound stimuli.

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STIMULUS CONTROL IN PIGEONS FOLLOWING VARIED LENGTHS OF DISCRIMINATION TRAINING WITH COMPOUND STIMULI

by
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B.A. (Hons.), University of Windsor, 1974

A Thesis
Submitted to the Faculty of Graduate Studies through the Department of Psychology in Partial Fulfillment of the Requirements for the Degree of Master of Arts at the University of Windsor

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ABSTRACT

Three groups of pigeons were tested for stimulus control following varied lengths of discrimination training with compound stimuli. A comparison between components tests and generalization tests with respect to sensitivity in the measurement of stimulus control was also carried out. The birds were trained to discriminate a vertical line on a green surround as the S+ from a horizontal line on a red surround as the S-. Following 5, 16 or 20 hours of this training, two sessions of components testing and two sessions of generalization testing were administered. Significant differences in the responses to the green stimulus were revealed, however, responses to the vertical line or the compound stimulus were insignificant. Differences in the slopes of the gradients were not significant, however, all groups produced gradients with non-zero slope. The generalization tests proved to be more sensitive to the line-tilt dimension. Components tests though, were sensitive to compound stimulus control. Further research is suggested with respect to the interaction between length of training, type of training stimuli and the type of testing procedures.

PREFACE

I would initially like to thank Dr. Theodore T. Hirota, Chairman of my Thesis Committee, for his encouragement and patient guidance in compiling the present manuscript. His inspiration and technical expertise proved to be invaluable.

I also wish to extend my gratitude to Dr. Jerome S. Cohen for consenting to be a member of my Committee. His advice and criticisms were greatly appreciated.

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CHAPTER I

Introduction

The concepts of attention and stimulus control have frequently been used in the study of animal learning. Lashley (1938) trained his rats to jump consistently toward a square stimulus as opposed to an inverted triangle. The rats were then tested with either the top half or the bottom half of the stimuli blackened out. Consistent choice behaviour was maintained when the lower halves of the stimuli remained visible. However, if the lower halves of the stimuli were blackened out, the rats responded randomly. During testing, the fact that only the lower portions of the stimuli elicited the jump response in Lashley's rats implied that the rats were attending just to the lower portion of the stimulus display. By blackening out parts of the stimuli, Lashley was able to isolate the portion of the stimulus which exerted control over the rats' behaviour.

Skinner (1953) described the controlling relationship between a particular part or aspect of the environment and a response as attention. In general, if independent variation of an aspect of the environment brings about variation in an organism's behaviour, then, the organism is assumed to be attending to that aspect of the environment.

Stimulus control may be observed when ".... differences in responding are caused by differences in the stimuli presented to the subjects (other features of the situation remaining constant)" (Honig, 1970). Typically, the terms stimulus control and attention have been used synonymously. If the behaviour of an organism is controlled by a stimulus or an aspect of it, it is assumed that the subject is attending to that aspect of the stimulus. Conversely, lack of control has been associated with lack of attention. However, if testing procedures do not reveal stimulus control, it is not necessarily due to lack of attention. The use of a more sensitive testing procedure (Farthing and Hearst, 1970) may provide evidence for the development of stimulus control.

A commonly used measure of stimulus control is the generalization gradient in which a systematic relationship between an ordered set of stimuli and responses may be observed. The generalization test involves random presentation of test stimuli varied symmetrically around the training stimulus. Response rates usually decrease as the difference between the training stimulus and the test stimuli increases, producing a gradient sloping on either side of the positive stimulus with a peak at the positive stimulus. A peaked gradient is regarded as an indication of stimulus control along the training dimension. A flat gradient, or a gradient whose slope is zero, has become associated with little or no control along that dimension.

The components test has frequently been used as an alternate measure of stimulus control (Reynolds, 1961; Eckerman, 1967; Johnson and Cumming, 1968; Born and Snow, 1970). Components testing involves separate presentation of each aspect or component part of each training stimulus. The number of responses emitted to each component of the compound stimulus is regarded as an indication of the extent to which the subject utilizes each aspect of a stimulus in solving a discrimination problem. Both the generalization test and the components test are administered following a criterion level of performance. Testing is conducted under extinction conditions (no reinforcement) since concern is focussed upon the number of responses the subject makes in the presence of each test stimulus before extinction is complete.

Apparently, stimulus control becomes fairly well-developed following differential training (Terrace, 1966). This training technique involves repeated reinforcement of one stimulus while a second stimulus is associated with non-reinforcement. But, several studies have demonstrated that if the positively reinforced stimulus (S+) is composed of compounded elements (i.e. form superimposed upon colour), stimulus control by one dimension is common (Reynolds, 1961; Eckerman, 1967; Johnson and Cumming, 1968; Farthing and

Hearst, 1970).

Using a components test, Reynolds (1961) examined stimulus control in a compound discrimination. He trained two pigeons to discriminate a white triangle on a red surround as S+ from a white circle on a green surround as S−. When the birds were presented with the four elements separately (white circle, white triangle, green surround, red surround) under extinction conditions, Reynolds found that one of the birds restricted its responding almost entirely to the red stimulus while the other bird responded mainly to the white triangle. Reynolds concluded that each pigeon had attended to only one of the two aspects of the compound stimulus. The other dimension of the S+ had exerted no control over responding.

Eckerman (1967) and Johnson and Cumming (1968) provided further evidence for stronger control by one dimension as opposed to a second dimension. Components tests were used in both studies. Eckerman (1967) trained his birds initially for 25 sessions to respond to each component to be used in subsequent compound stimuli. This procedure insured that response rates were equal for all components at the outset of discrimination training. Following these preliminary training sessions, 10 sessions of training with the compound stimuli were given. A vertical white line on a green surround was S+ and a horizontal white line on a red surround was S-. Eckerman found selective control of responding by colour for the reinforced stimulus. All birds responded predominantly to the green surround of the S+. No differences were observed in response suppression during presentations of the elements of the non-reinforced stimulus. Response rates were consistently low in the presence of both the red surround and the horizontal white line. The chromatic surround of the positive stimulus seemed to dominate control of responding. However, one of the three birds responded more to the positive line-tilt than to the negative line-tilt. Thus, some evidence for control by line is suggested.

Johnson and Cumming (1968), in the first of three studies, employed two pigeons to test for stimulus control. Each bird received five sessions of compound discrimination training. The S+ was a white vertical line on a green surround and the S- was a white horizontal line on a red surround. The results of the components test revealed stronger control by the positive wavelength. Both birds emitted a greater proportion of responses to green than they did to the vertical line. Little difference was noted in the control of response suppression in the presence of either element of the non-reinforced stimulus. However, responses to the positive line-tilt were greater than those to the negative line-tilt. These results indicate a degree of control over responding by the line-tilt dimension.

Farthing and Hearst (1970) provided some support for the hypothesis that wavelength control is dominant over line-tilt control in the pigeon. Three groups of pigeons were used. Group 1 was trained for five sessions (30 S+ and 30 S- presentations each) with a white vertical line on a blue surround as S+ and a horizontal line on a green surround as S-. Group 2 received 10 sessions of training with a blue surround only (S+) and a green surround only (S-) followed by five sessions of compound training as Group 1. Group 3 received 10 sessions with a vertical line only (S+) and a horizontal line only (S-) followed by five compound stimulus sessions. Of primary concern was the difference in testing procedures. Components tests as well as compound "opposed cues" tests, in which positive and negative elements were combined, were compared. Blocking effects, in which one cue becomes dominant over another, were also examined. Farthing and Hearst (1970) proposed that pre-training with a single-cue discrimination would result in control by that cue to the exclusion of the alternate cue. The components test revealed that line orientation presented separately exercised little control over responding. Maximum responding occurred in the presence of the positive colour, blue. However, the opposed cues test, composed of the combination of the positive colour and negative line-tilt, revealed that fewer responses were emitted to blue-horizontal (positive colour and negative line-tilt) than to blue-vertical (both cues positive). Farthing and Hearst proposed that the compound opposed cues tests were more sensitive to control by the line-tilt dimension. They interpreted their results as being suggestive of the fact that the birds did learn something about line-tilt during training. Possibly, opposed cues tests are more sensitive to line-tilt control in pigeons. However, the fact that some of the birds in the Eckerman (1967) and the Johnson and Cumming (1968) studies revealed slightly greater responding to the positive line-tilt during a simple components test suggests that differences in training procedures may also contribute to differences in test results.

Born and Snow (1970) also conducted a comparison of testing procedures. In this case, generalization tests and components tests were evaluated. Each of three groups of pigeons was trained to discriminate a white vertical line on a green surround from either a green surround (no line), a red surround (no line) or a white vertical line on a red surround. Group 1 (green surround as S-) could learn the discrimination upon line presence or absence only. Group 2 (red surround as S-) could learn the discrimination upon the basis of colour differences or upon the presence-absence of the vertical line. Group 3 (white vertical line on red surround as S-) could learn the discrimination on the basis of colour differences only. Three days of testing followed training. Generalization gradients with non-zero slope (maximum responding occurring at the positive stimulus value) were obtained from each group. However, the components test indicated that maximum responding occurred during presentations of the compound positive stimulus (vertical line on a green surround). Response rates for each of the separate components were consistently low. All groups, including Group 3, which could have based its responses solely upon colour, showed a response pattern in which maximum responding was emitted to the combination of the vertical white line coupled with the green surround. Born and Snow could not explain why they obtained gradients with non-zero slope for all their groups. However, Hirota (1974) obtained sloped gradients for his training groups as well. Hirota utilized stimuli similar to those with which Newman and Baron's (1965) Groups 2 and 4 were trained. Steep gradients followed Hirota's (1974) training procedures. But, Born and Snow (1970) and Hirota (1974) used extended training procedures. Both these studies employed at least 3.8 (Hirota, 1974) to 10.2 (Born and Snow, 1970) hours of training beyond that of Newman and Baron (1965). Extended training or overtraining has often been followed by steepened gradients (Hearst and Koresko, 1968). Newman and Baron (1965) obtained sloped gradients for their Group 1 only which was trained with a white vertical line on a green surround as S+ and a green surround (no line) as S-. Flat gradients were obtained from the birds in the other two groups presented with a discrimination problem containing relevant colour cues. Newman and Baron's results suggested that clour cues were more salient for their birds. But if pigeons attend to wavelength rather than line-tilt in a discrimination problem with relevant colour cues, then Born and Snow (1970) should not have obtained gradients with non-zero slope along the dimension of angularity. During the components test, maximum responding to the combination of positive colour and line should also not have occurred.

Since Born and Snow (1970) utilized Newman and Baron's (1965) stimuli and obtained compound control of responding during the components test as well as steep generalization gradients, variation in results due to differences in stimuli may, perhaps, be ruled out. Farthing and Hearst (1970) using quite different stimuli, found compound stimulus control through opposed cues tests even though it seemed that colour was the initial controlling factor. In view of the above results, primary interest should be concentrated upon the circumstances under which control by compounds or elements occurs.

The literature dealing with stimulus control by the separate elements as well as the combined elements of the compound stimuli yields discrepant results. Studies by Reynolds (1961) and Johnson and Cumming (1968) indicate that behaviour may be controlled predominantly by one aspect of the stimulus compound. Other studies (Born and Snow, 1970; Farthing and Hearst, 1970) indicate that behaviour may be controlled by both aspects of the stimulus complex.

In the area of classical conditioning, stimulus control by both elements of the compound stimulus commonly occurs. Baker (1968) cites Russian studies which suggest that compound stimulus control is most frequently observed. When compound and components tests were used, control by separate elements was usually found to be weaker than control by the compounded elements.

There is an indication that procedural differences between the previously cited studies may account for the discrepancies in the results. Specifically, there may be reason to believe that the total number of hours invested in the training phase itself, could, perhaps, be the crucial factor. Length of training influences control by line-tilt as evidenced by Hearst and Koresko (1968), Born and Snow (1970) and Hirota (1974). Length of training also influences the results obtained during components testing as evidenced by the discrepant results obtained by Reynolds (1961), Johnson and Cumming (1968), Born and Snow (1970) and Farthing and Hearst (1970). An analysis of the relevant studies with respect to the total number of hours devoted to discrimination training may facilitate comparisons.

Closer examination of the Reynolds (1961) study reveals that the birds were exposed to six daily sessions of discrimination training. Each of these sessions was three hours in duration. Both the positive and the negative stimuli appeared 30 times each and each presentation was three minutes in duration. In total, 18 hours were devoted to discrimination training. On the other hand, Johnson and Cumming (1968) trained their birds for only five one-hour sessions (five hours total). Eckerman (1967) administered 25 hours of initial training to the separate components followed by 10 hours of training in the compound discrimination.

Born and Snow (1970) gave their birds 12 sessions of discrimination training. Each session was 80 minutes in duration. Both the S+ and the S— were presented 20 times each and each stimulus presentation was of a two-minute duration. This procedure resulted in a total of 16 hours of training.

Farthing and Hearst's (1970) Group 1 showed stronger control by wavelength, but the birds in this group received only 2.5 hours of discrimination training. Although Farthing and Hearst gave the birds in Groups 2 and 3 preliminary single-cue training to either colour or line-tilt, worthy of note is the fact that this prior training produced no blocking effects. Following 5 hours of single-cue training and 2.5 hours of compound-cue training (7.5 hours total) opposed cues tests indicated that the birds in Groups 2 and 3 seemed to learn something about both cues.

In order to make direct comparisons of the relevant features of the previously cited studies, an examination of Table 1 is recommended. Information regarding the number of hours invested in discrimination training and the resultant type of control, uni-dimensional (single-cue) or multi-dimensional (compound-cue), is summarized.

The fact that stronger control by a single dimension has been revealed in studies employing 2.5 to 10 hours as well as 18 hours of discrimination training seems to imply that a minimum amount of training and training beyond a certain maximum may be responsible for evidence of this type of control. On the other hand, compounding, or the use of both aspects of the stimulus in conjunction with one another occurred when 16 hours of training was given to the

TABLE 1

A Summary of the Variations in the Length of Discrimination Training and the Resultant Type of Stimulus Control for the Relevant Studies

Authors	Hours of Training Prelim.	Hours of Training Disc.	Type of Control
Farthing and Hearst (1970)		2.5	uni-dimensional
Johnson and Cumming (1968)		5.0	uni-dimensional
Eckerman (1967)	25.0	10.0	uni-dimensional
Reynolds (1961)		18.0	uni-dimensional
Farthing and Hearst (1970)	5.0	2.5	multi-dimensional
Born and Snow (1970)		16.0	multi-dimensional

subjects (Born and Snow, 1970). Stronger control by the compound stimulus as training progresses is in keeping with the Russian literature. Razran (1965) cited a study by Platonov (1912) utilizing classical conditioning procedures. Platonov found that as training progressed, responding gradually became dominated by the compound stimulus. In order to assess control by compounds and components in pigeons following a visual discrimination, adequate testing procedures must be utilized. A simple components test detected control by the compound following 16 hours of training. However, when a more sensitive test is administered, (Farthing and Hearst, 1970), stimulus control by a second dimension may be observed following 2.5 hours of training. Possibly, following 16 hours of training, stimulus control by both elements may be sufficiently developed to be detected by a simple components test while a more sensitive test is required to demonstrate compound control following 2.5 hours of training. Therefore, a direct investigation of the effects of the amount of discrimination training and type of testing procedures may provide some insight into the conditions under which control by one or both aspects of a compound stimulus display may be observed.

Purpose of the Present Investigation

The present study was, therefore, designed to investigate the effects of the amount of discrimination training upon stimulus control in a compound stimulus discrimination. An investigation into the sensitivity of two types of testing procedures was also conducted. The stimuli employed by Johnson and Cumming (1968) were used. Following 5, 16 and 20 hours of discrimination training for each of Groups 1, 2 and 3 respectively, components tests and generalization tests were used to assess stimulus control of the compound stimulus and its elements. The components tests consisted of separate presentations of a red surround, a green surround, a vertical white line and a horizontal white line each projected onto an achromatic surround. The positive and the negative stimuli presented during the training phase were also included in the test phase as control stimuli. The proportion of the responses emitted to each element relative to the responses emitted to the positive compound were compared for each group. Generalization testing succeeded components testing. Generalization testing was along the angularity dimension with stimuli 0° (vertical), 22.5° and 45° to the left or right of vertical.

On the basis of the evidence contained in the previously cited literature, it was hypothesized that:

(1.) The subjects receiving 5 hours of discrimination training (Group 1) would show some evidence of line-tilt control, however, control by wavelength would be stronger.

(2.) Components test would indicate compound stimulus control of responding for the birds in Group 2 after 16 hours of discrimination training.

(3.) Components test would show some evidence of single-cue control for the birds in Group 3 (20 hours of training).

(4.) Generalization tests should prove to be sensitive to line-tilt control in Group 1. Consequently all gradients should be sloped.

(5.) Group 2 should produce the sharpest gradients.

CHAPTER II

Method

Subjects

The subjects were 24 naive adult male White Carneaux pigeons, one to two years of age. They were reduced to approximately 80% ($\pm$ 10 g.) of ~~their~~ free-feeding body weights through food-deprivation and maintained at this level throughout the duration of the experimental period. Water was available in the subjects' home cages at all times.

Apparatus

Two LeHigh Valley one-key pigeon chambers were used. The panel in each chamber contained a 1-inch diameter key located 8.50 inches above the floor. A 2-inch square feeder opening was positioned 5.0 inches below the key. The stimuli were projected onto the reverse side of the translucent response key by Grason-Stadler In-Line Digital Display Units. The stimuli were either a vertical white line or a horizontal white line 3/16th of an inch wide projected onto an illuminated background. Colour was added to the background by automatically switching on lights behind a red or green Grason-Stadler filter. The lines were projected at five different angular orientations ranging from 45° counterclockwise to 45° clockwise from vertical (0°) in 22.5° steps. Colour and line could also be presented separately with the lines appearing on an achromatic (black) surround. White noise was presented continuously during the experimental sessions via a speaker in each experimental chamber. During 3 second reinforcement periods, the feeder light replaced the houselight. A system of relays, timers and steppers, located in an adjacent room, programmed the experimental sessions and all responses were automatically recorded on digital counters.

Procedure

<u>Preliminary training</u>. On Day 1, all birds received magazine and key-peck training by successive approximations. For each subject, fifty continuously reinforced responses were allowed to S+ on each of Days 1 and 2, for a total of 100 continuously reinforced responses. During this training, a vertical white line on a green background was present continuously on the key for all groups except during reinforcement.

<u>Discrimination training</u>. On Day 3, all subjects were gradually shifted to a variable interval reinforcement schedule with a mean interval of 30 seconds (VI 30 seconds). and received a total of 50 reinforcements. At the end of

Day 3, all birds were assigned to one of three matched groups on the basis of their response rates to S+ during Day 3 of training. This procedure ensured that subjects with both high and low response rates were equally distributed within the separate groups. On Day 4, all subjects were shifted to a multiple VI 30 second extinction schedule and maintained on this schedule for the remaining days of training. Each daily session consisted of thirty 60-second presentations of the reinforced component (S+) alternated with thirty 60-second presentations of the non-reinforced component (S-) in an ABBA BAAB sequence. Two reinforcement periods were scheduled for each 60-second presentation of S+. Scheduling reinforcement periods in this manner ensured that the birds would experience reinforcement in the presence of S+ even if key-pecking behaviour was not continuous or excessive during an S+ presentation. When a reinforcement was programmed, the S+ would remain on the key until a response was initiated by the subject. One key-peck response was adequate to produce reinforcement.

For all groups, S+ was a vertical white line on a green surround while S- was a horizontal white line on a red surround. Group 1 received 5 hours of discrimination training with these stimuli while Groups 2 and 3 received 16 and 20 hours of discrimination training respectively.

<u>Components testing</u>. Following discrimination training, all subjects received two sessions of components testing. A warm-up session preceded each test session. The warm-up consisted of six alternations of S+ and S-, each presentation being 60 seconds in duration. Two reinforcements were available during each S+ presentation. The test stimuli consisted of each component of the training stimuli (red surround, green surround, vertical white line and horizontal white line projected onto an achromatic surround) as well as each of the original compound training stimuli. Each 60-second stimulus appeared 8 times during each day of testing. The presentation of test stimuli was randomized with the restriction that the positive stimulus (vertical white line on a green surround) would never appear first during the test days. Testing was conducted under extinction conditions.

<u>Generalization testing</u>. Following components testing, all subjects received two sessions of generalization testing. The warm-up session was identical to that which preceded the components test. The test stimuli consisted of five line orientations: vertical (0°) and 22.5° and 45° to the left or right of vertical (the original training stimulus). Each stimulus appeared 10 times each for a duration of 45

seconds. The vertical line never appeared first during the test days, and the stimuli were presented in an incomplete counterbalanced order. Generalization testing was also carried out under extinction conditions.

CHAPTER III

Results

Discrimination Training

All birds acquired the discrimination. Appendix B contains the acquisition data for all three groups during the entire course of training. A graphic representation of mean response rates to S+ and S- across all training sessions for each group is depicted in Figure 1. Discrimination ratios (total pecks to S+ divided by total pecks to S+ and S-) were calculated for each bird for the last day of discrimination training. All birds produced discrimination ratios ranging from .97 to 1.00 (perfect discrimination) except for bird 2061 (.59). Bird 2061 from Group 1 initially responded minimally to S- but the response rate increased across training sessions. However, the overall mean ratio for Group 1 (.94) was relatively unaffected by the perfomance of this bird. Groups 2 and 3 both produced mean ratio values of .99. This data suggests that the birds acquired the discrimination with relatively equal facility.

Components Test

The order of presentation of the six test stimuli is presented in Appendix C. Appendix D contains the mean total responses to each test stimulus for all three groups, on Day 1 of testing and Appendix E contains the mean total responses for the three groups for Day 2 of testing. The means for Day 1 of testing are also represented graphically in Figure 2.

A two-factor analysis of variance with repeated measures was performed on the total number of responses of all three groups to all components test stimuli on Day 1 of testing. The results of this analysis are presented in Table 2. No treatment effect of Groups (A) occurred. However, a significant Stimuli (B) effect ($F=100.22$, $df=5/105$, $p<.01$) occurred indicating a difference in responding between stimuli. A significant Groups x Stimuli (A x B) interaction effect ($F=2.21$, $df=10/105$, $p<.05$) indicated that group differences did occur in responding to some of the stimuli. Inspection of Figure 2 would suggest that the main differences between the groups was a result of differences in responses to both the green stimulus and S+. To examine group differences in responding to the green stimulus, a one-way analysis of variance was performed on total responses of the three groups to the green stimulus only. A significant difference between groups was indicated ($F=24.61$, $df=2/21$, $p<.01$). The results of a Newman-Keul's comparison of group means are shown in Table 4. The Newman-Keuls test indicated significant differences between Groups 1 and 2, 1 and 3 and Groups 2 and 3. When these results are compared to the graphic data contained in Figure 2, the Newman-Keuls test indicates that Group 3 emitted significantly more responses to the green stimulus than either Groups 1 or 2. Group 2 also responded significantly more to green than did Group 1. Thus, an increase in the number of responses to colour as a consequence of an increase in the number of hours of training is suggested.

To test the hypothesis that Group 2, trained for 16 hours, would show greater compound-cue control, a one-way analysis of variance was performed on total responses of each group to S+ (the original compound training stimulus.) The results of this analysis are shown in Table 5. No significant differences between groups were obtained.

Analysis of variance on total responses to each stimulus for all groups on Day 2 of testing provided no significant Groups x Stimuli (A x B) interaction effects. Therefore, no significant differences between groups existed on Day 2 of testing. The means for Day 2 of testing are presented in Figure 3.

In order to reduce the effects of individual variability, relative response measures were tabulated. This was accomplished by calculating response ratios (total responses to each stimulus divided by total responses to all stimuli

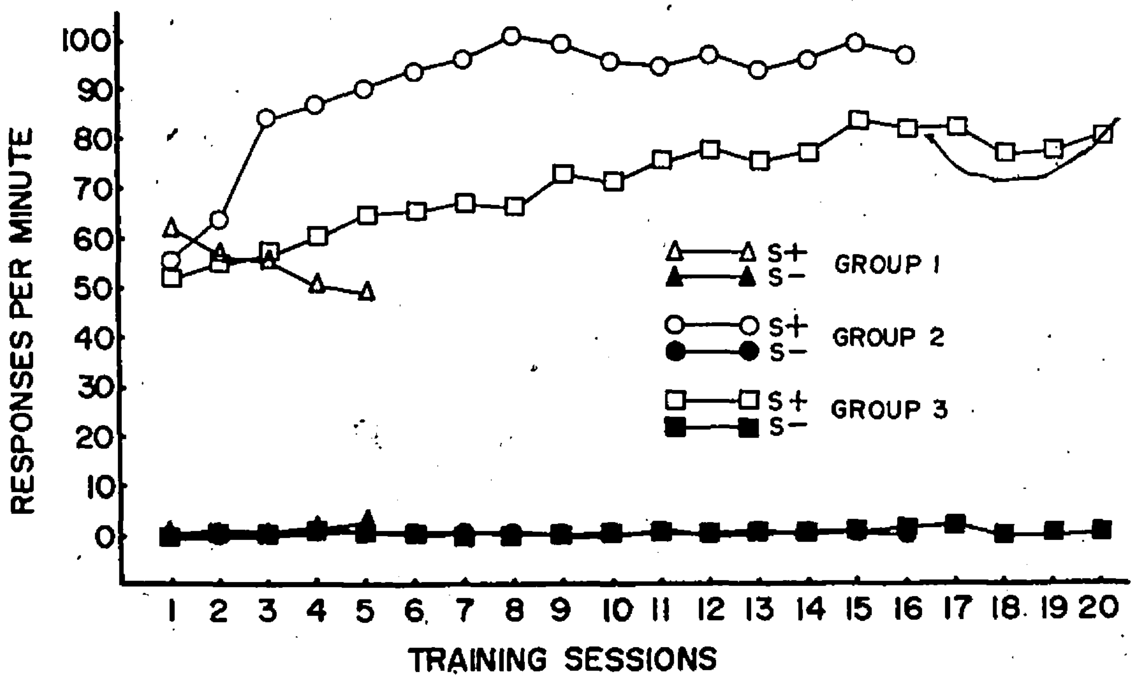

Fig. 1. Mean number of responses per minute to S+ and S− during discrimination training.

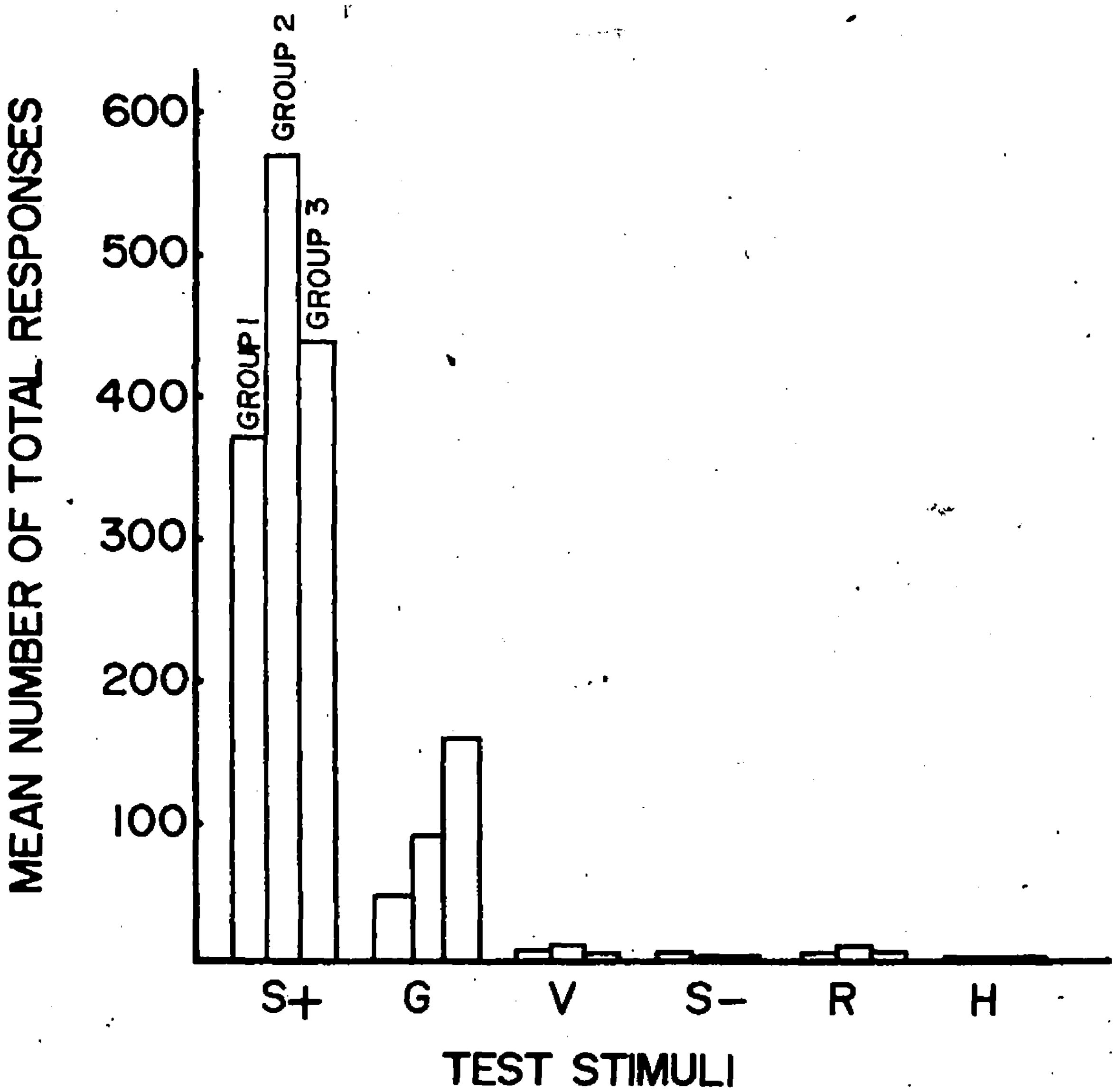

Fig. 2. Mean number of responses to each test stimulus for the three training groups for the first day of components testing.

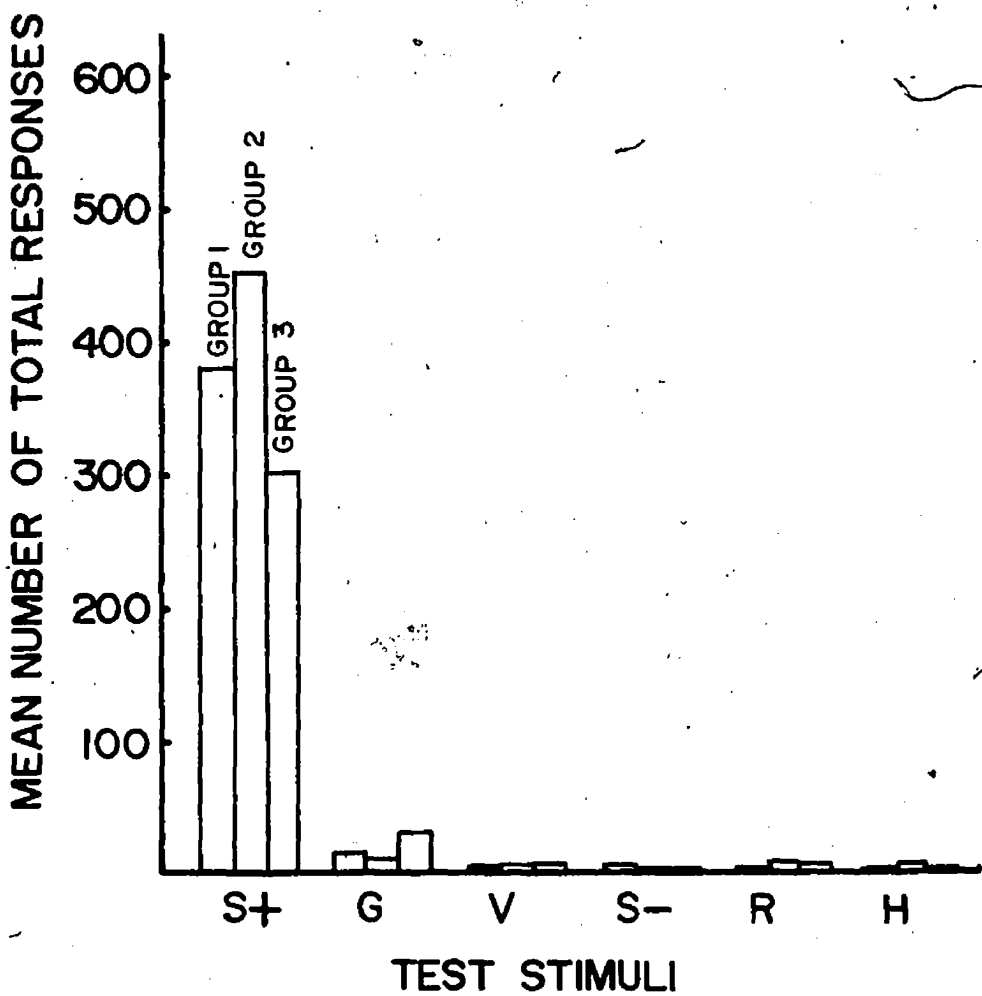

Fig. 3. Mean number of responses to each test stimulus for the three training groups for the second day of components testing.

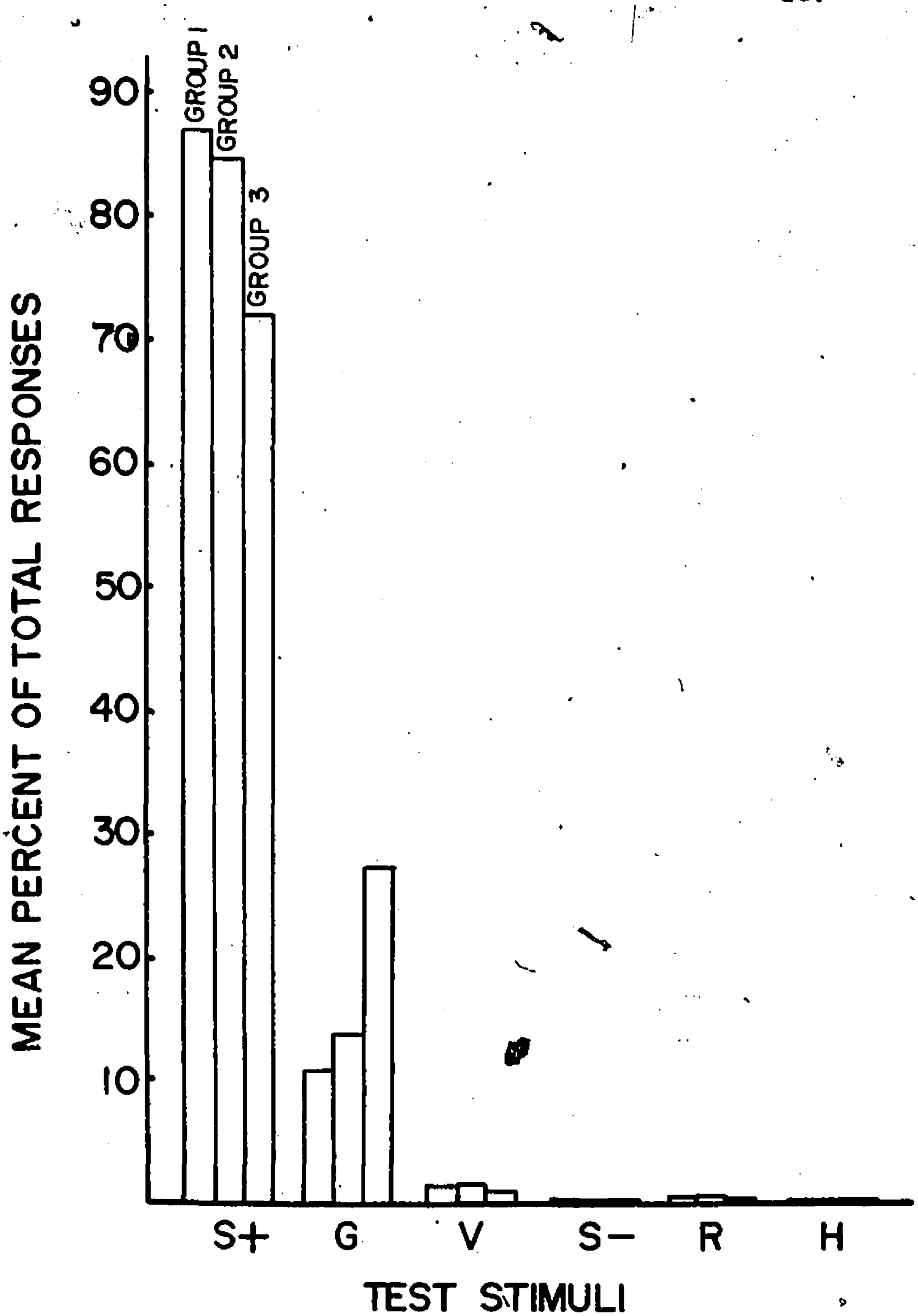

Fig. 4. Mean percent of total responses to all test stimuli for the three training groups on the first day of components testing.

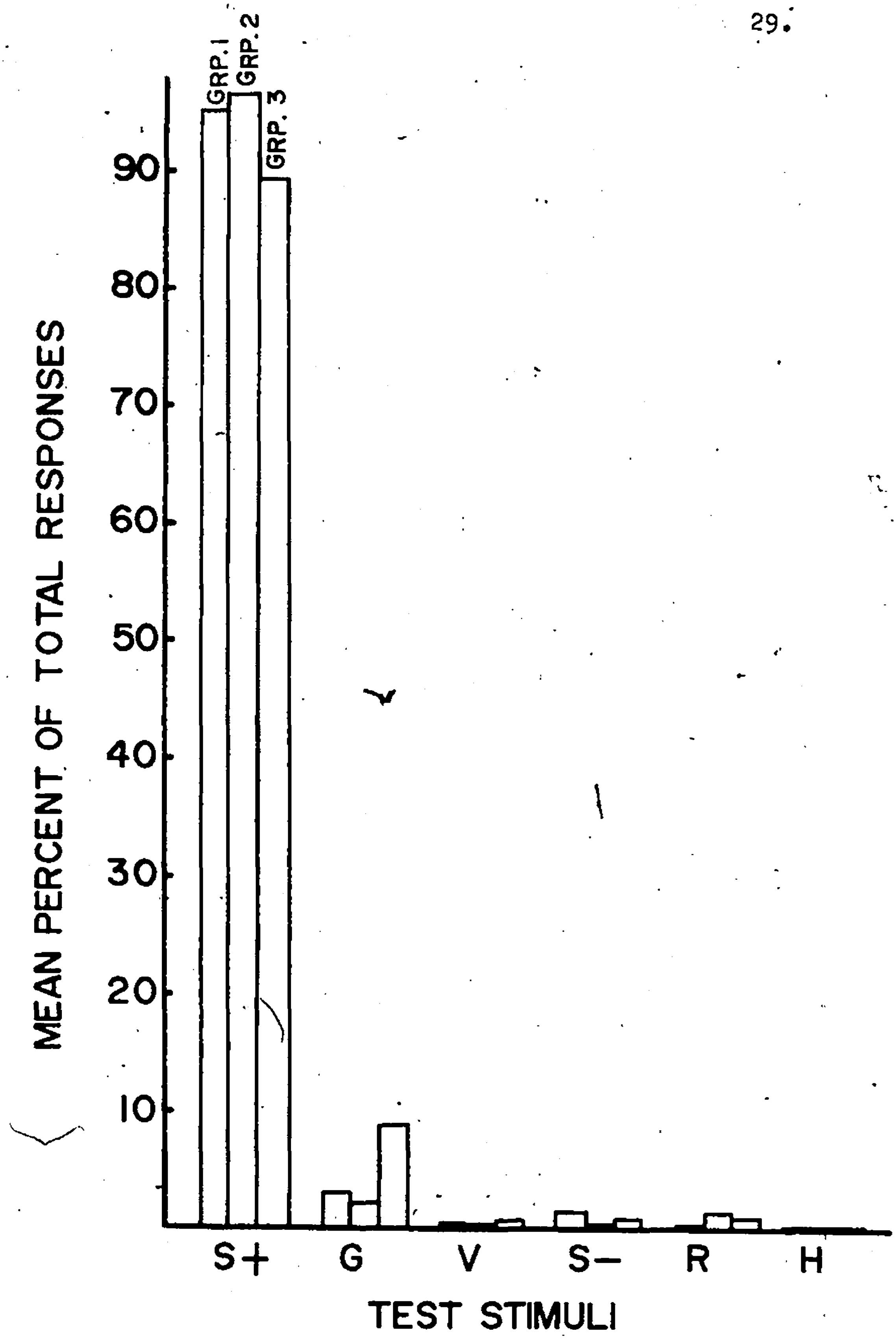

Fig. 5. Mean percent of total responses to all test stimuli for the three training groups on the second day of components testing.

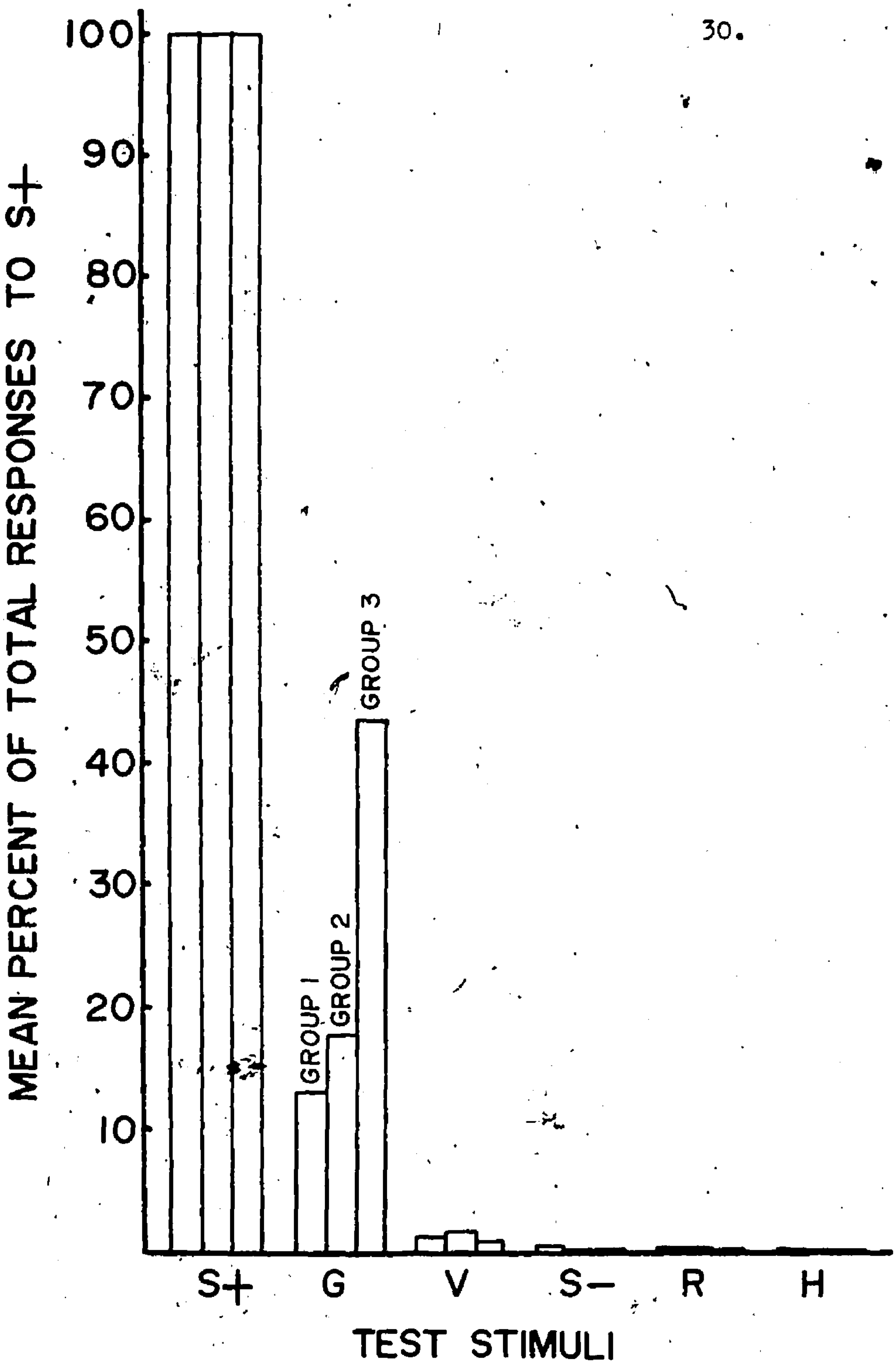

Fig. 6. Mean percent of responses to each test stimulus relative to total S+ responding on the first day of components testing.

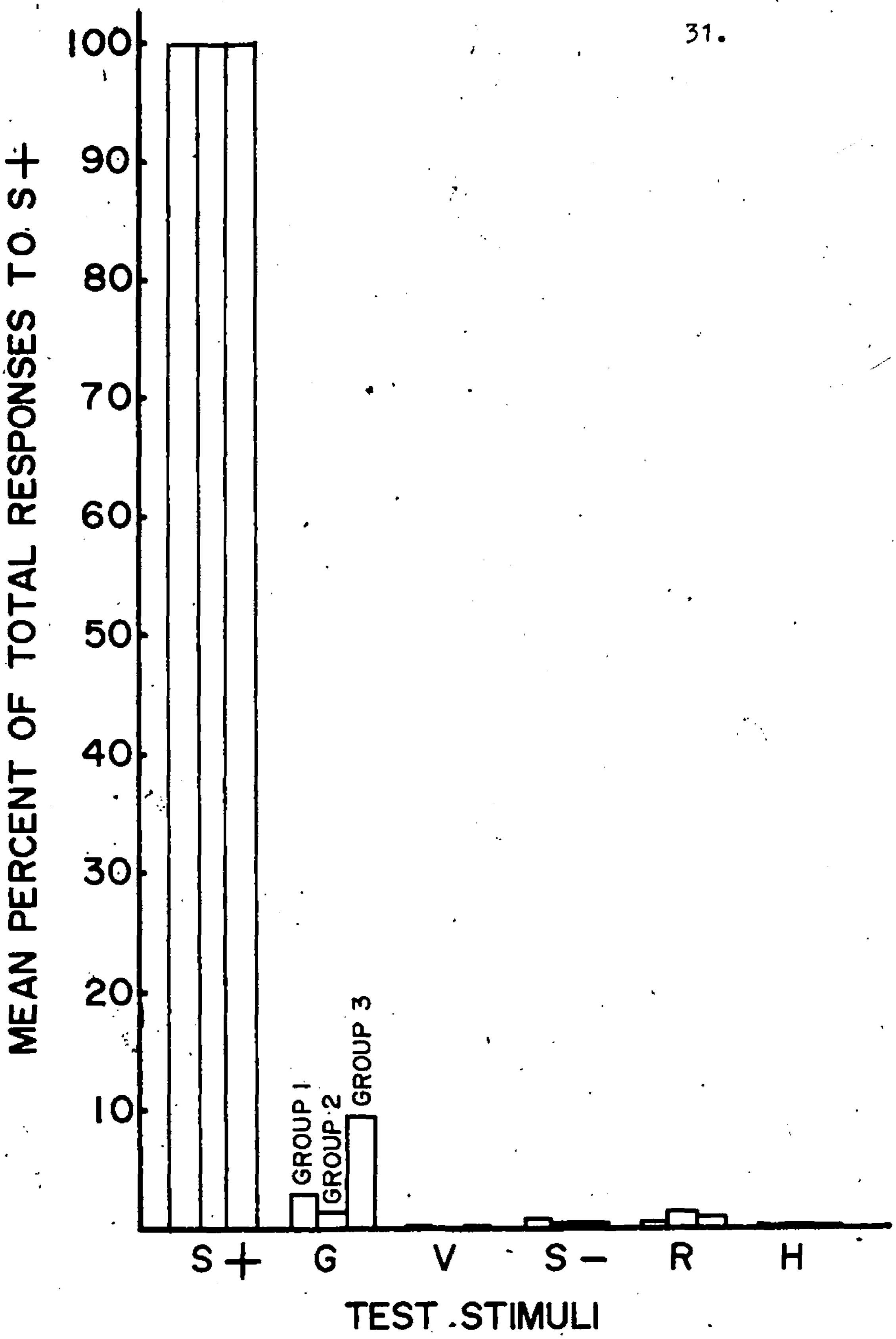

Fig. 7. Mean percent of responses to each test stimulus relative to total S+ responding on the second day of components testing.

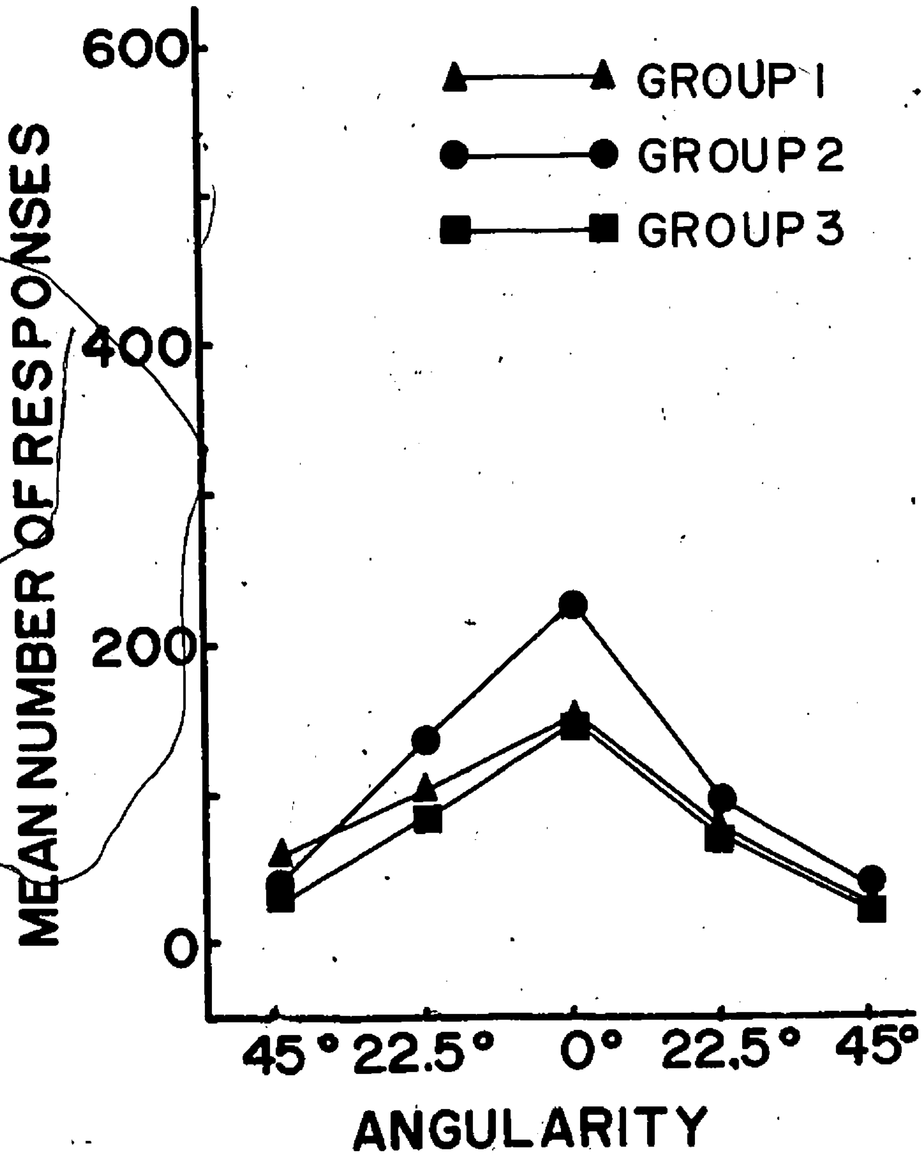

Fig. 8. Absolute generalization gradients for the three training groups for the first day of generalization testing.

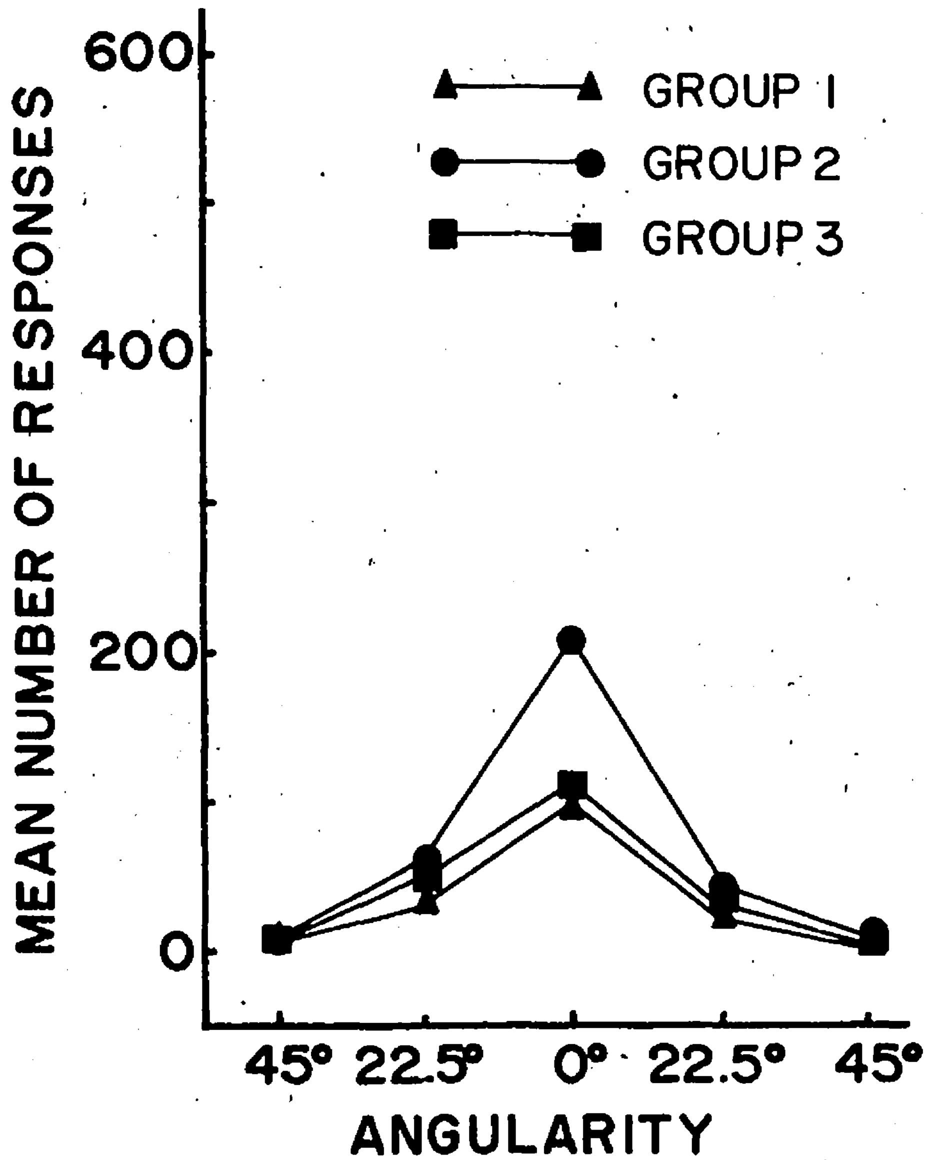

Fig. 9. Absolute generalization gradients for the three training groups for the second day of generalization testing.

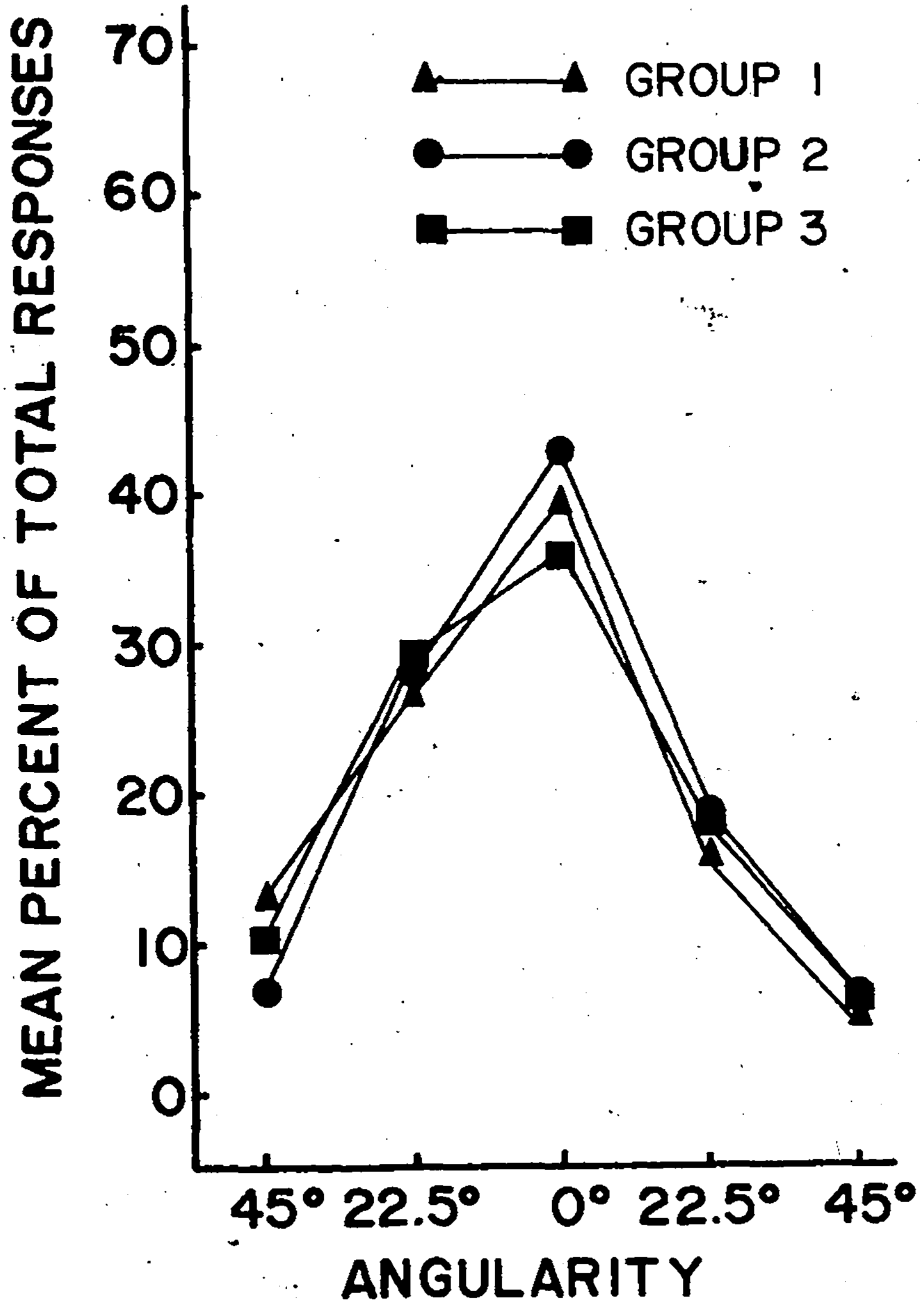

Fig. 10. Relative generalization gradients for the three training groups for the first day of generalization testing.

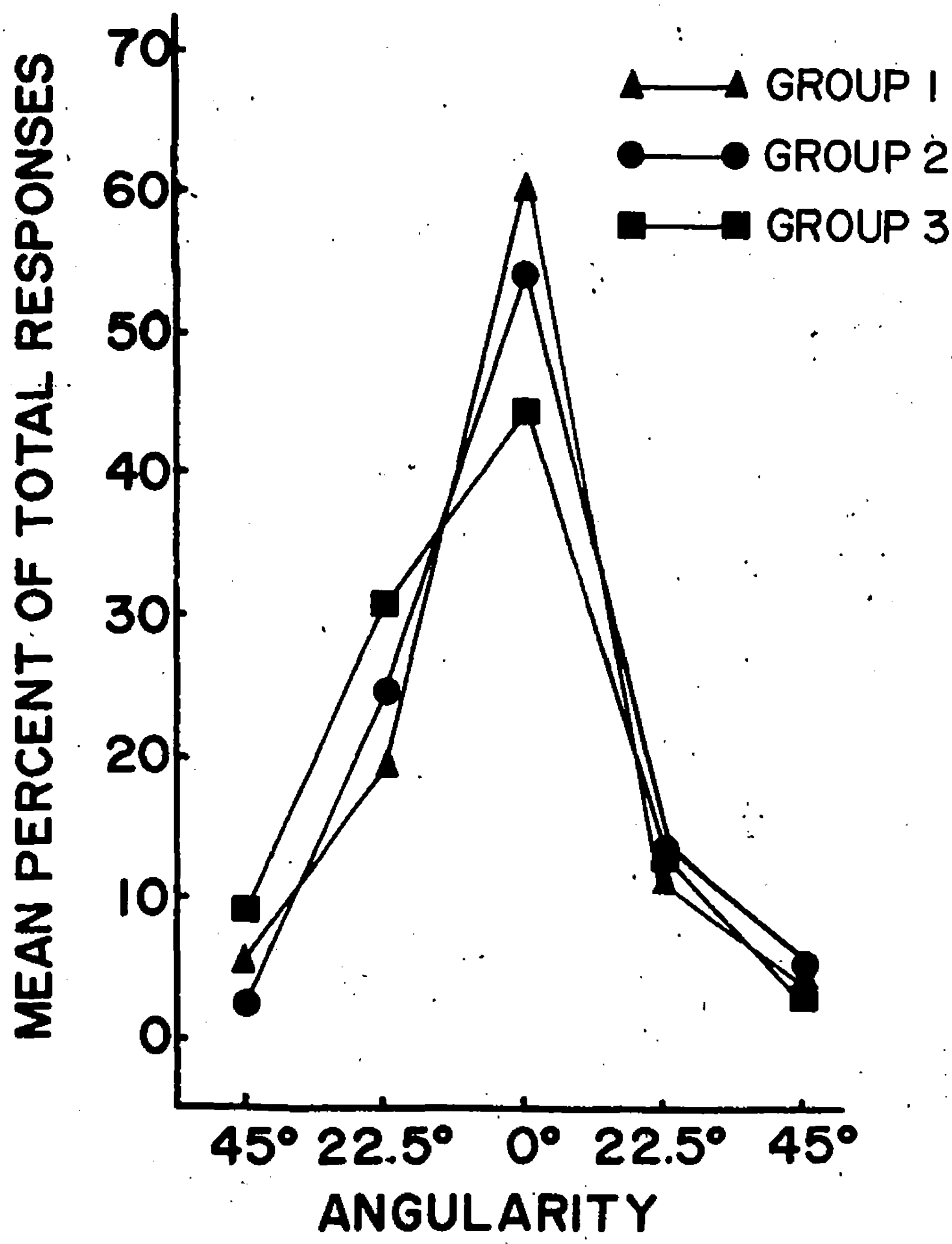

Fig. 11. Relative generalization gradients for the three training groups for the second day of generalization testing.

TABLE 2

Analysis of Variance of Total Number of Responses for All Training Groups to All Test Stimuli on Day One of Components Testing

Source	SS	df	MS	F
<u>Between subjects</u>				
A (Groups)	43334.59	2	21667.29	2.77
Subj. w. groups	163792.29	21	7799.63	
<u>Within subjects</u>				
B (Stimuli)	3967306.72	5	793461.34	100.22 **
AB	175097.15	10	17509.71	2.21 *
B X subj. w. groups	831241.45	105	7916.58	

* $p < .05$

** $p < .01$

TABLE 3

Analysis of Variance of Total Number of Responses for All Training Groups to the Green Stimulus on Day One of Components Testing

Source	SS	df	MS	F
Between	50183.58	2	25091.79	24.61 **
Within	21409.50	21	1019.50	
Total	71593.08	23		

* $p < .05$
** $p < .01$

TABLE 4

Newman-Keuls Comparison of Mean Number of Responses for All Training Groups to the Green Stimulus on Day One of Components Testing

	Group 1	Group 2	Group 3
Group 1	-	3.62 *	9.81 **
Group 2	-	-	6.19 **

* $p < .05$
** $p < .01$

TABLE 5

Analysis of Variance of Total Number of Responses for All Training Groups to S+ on Day One of Components Testing

Source	SS	df	MS	F
Between	168243.60	2	84121.80	2.09
Within	841696.40	21	40080.78	
Total	1009940.60	23		

* $p < .05$

** $p < .01$

TABLE 6

Analysis of Variance of Total Number of Responses for All Training Groups to All Test Stimuli on Day Two of Components Testing

Source	SS	df	MS	F
Between subjects				
A (Groups)	11140.59	2	5570.29	1.06
Subj. w. groups	109960.89	21	5236.23	
Within subjects				
B (Stimuli)	2737502.36	5	547500.47	106.71 **
AB	79967.23	10	7996.72	1.55
B X subj. w. groups	538686.22	105	5130.34	

* $p < .05$

** $p < .01$

TABLE 7

Analysis of Variance of Percent of Total Responses for All Training Groups to All Test Stimuli on Day One of Components Testing

Source	SS	df	MS	F
Between subjects				
A (Groups)	0.0000	2	0.0000	0.18
Subj. w. groups	0.0002	21	0.0000	
Within subjects				
B (Stimuli)	124515.44	5	24903.08	383.37 **
AB	2313.05	10	231.30	3.56 **
B X subj. w. groups	6820.62	105	64.95	

* $p < .05$
** $p < .01$

TABLE 8

Analysis of Variance of Percent of Total Responses for All Training Groups to the Green Stimulus on Day One of Components Testing

Source	SS	df	MS	F
Between	1248.09	2	624.04	3.83 *
Within	3413.29	21	162.53	
Total	4661.38	23		

* $p < .05$
** $p < .01$

TABLE 9

Newman-Keuls Comparison of Mean Percent of Total Responses for All Training Groups to the Green Stimulus on Day One of Components Testing

	Group 1	Group 2	Group 3
Group 1	-	.65	3.68 *
Group 2	-	-	3.02 *

* $p < .05$

TABLE 10

Analysis of Variance of Percent of Total Responses for All Training Groups to S+ on Day One of Components Testing

Source	SS	df	MS	F
Between	1060.91	2	530.45	3.33
Within	3340.73	21	159.08	
Total	4401.64	23		

* $p < .05$

** $p < .01$

TABLE 11

Analysis of Variance of Percent of Responses to Green Relative to S+ for All Training Groups on Day One of Components Testing

Source	SS	df	MS	F
Between	4300.80	2	2150.40	4.10 *
Within	11011.62	21	524.36	
Total	15312.42	23		

* $p < .05$
** $p < .01$

TABLE 12

Newman-Keuls Comparison of Mean Percent of Total Responses to Green Relative to S+ for All Training Groups on Day One of Components Testing

	Group 1	Group 2	Group 3
Group 1	-	.51	3.76 *
Group 2	-	-	3.25 *

* $p < .05$

TABLE 13

Analysis of Variance of Percent of Total Responses for All Training Groups to All Test Stimuli on Day Two of Components Testing

Source	SS	df	MS	F
Between subjects				
A (Groups)	0.0000	2	0.0000	0.04
Subj. w. groups	0.0003	21	0.0000	
Within subjects				
B (Stimuli)	170413.76	5	34082.75	2194.44 **
AB	455.57	10	45.55	2.93 **
B X subj. w. groups	1630.79	105	15.53	

* $p < .05$
** $p < .01$

TABLE 14

Analysis of Variance of Percent of Total Responses for All Training Groups to the Green Stimulus on Day Two of Components Testing

Source	SS	df	MS.	F
Between	221.48	2	110.74	3.21
Within	724.06	21	34.47	
Total	945.54	23		

* $p < .05$
** $p < .01$

TABLE 15

Analysis of Variance of Percent of Total Responses for All Training Groups to S+ on Day Two of Components Testing

Source	SS	df	MS	F
Between	223.52	2	111.76	2.98
Within	785.42	21	37.40	
Total	1008.94	23		

* $p < .05$
** $p < .01$

TABLE 16

Analysis of Variance of Percent of Responses to Green Relative to S+ for All Training Groups on Day Two of Components Testing

Source	SS	df	MS	F
Between	275.14	2	137.57	2.36
Within	1222.32	21	58.20	
Total	1497.46	23		

* $p < .05$
** $p < .01$

TABLE 17

Analysis of Variance of Total Number of Responses for All Training Groups to All Test Stimuli on Day One of Generalization Testing

Source	SS	df	MS	F
Between subjects				
A (Groups)	25973.61	2	12986.80	0.77
Subj. w. groups	353608.17	21	16838.48	
Within subjects				
B (Stimuli)	322210.91	4	80552.72	18.06 **
AB	21268.13	8	2658.51	0.59
B X subj. w. groups	374632.95	84	4459.91	

* $p < .05$

** $p < .01$

TABLE 18

Analysis of Variance of Total Number of Responses for All Training Groups to All Test Stimuli on Day Two of Generalization Testing

Source	SS	df	MS	F
Between subjects				
A (Groups)	23779.11	2	11889.55	1.46
Subj. w. groups	170932.87	21	8139.66	
Within subjects				
B (Stimuli)	278930.78	4	69732.69	10.89 **
AB	40391.96	8	5048.99	0.78
B X subj. w. groups	537759.25	84	6401.89	

* $p < .05$

** $p < .01$

TABLE 19

Analysis of Variance of Percent of Total Responses for All Training Groups to All Test Stimuli on Day One of Generalization Testing

Source	SS	df	MS	F
Between subjects				
A (Groups)	0.058	2	0.029	0.864
Subj. w. groups	0.716	21	0.034	
Within subjects				
B (Stimuli)	17720.88	4	4430.22	28.23 **
AB	444.60	8	55.57	0.35
B X subj. w. groups	13180.15	84	156.90	

* $p < .05$

** $p < .01$

TABLE 20

Analysis of Variance of Percent of Total Responses for All Training Groups to All Test Stimuli on Day Two of Generalization Testing

Source	SS	df	MS	F
<u>Between subjects</u>				
A (Groups)	0.010	2	0.005	1.21
Subj. w. groups	0.091	21	0.004	
<u>Within subjects</u>				
B (Stimuli)	39138.91	4	9784.72	37.65 **
AB	1744.97	8	218.12	0.83
B X subj. w. groups	21289.95	84	259.88	

* $p < .05$

** $p < .01$

combined). A two-factor analysis of variance was then performed on percent of total responses emitted to each stimulus for Day 1 of components testing (Table 7). A Groups x Stimuli (A x B) interaction effect was obtained ($F=3.56$, $df=10/105$, $p<.01$). Inspection of Figure 4 indicates that relative responses to green and S+ account for the major differences between the three training groups. As indicated in Figure 4, the hypotheses that Groups 1 and 3, trained for 5 and 20 hours, respectively, would show greater evidence of single-cue control, was only partially supported. Group 3 did, in fact, show greater control by wavelength but Group 1 demonstrated the least control by wavelength. A one-way analysis of variance performed on the relative response measures to the green stimulus is summarized in Table 8. There was a significant difference in relative responses to the green stimulus ($F=3.83$, $df=1/23$, $p<.05$). A Newman-Keuls comparison of group means (Table 9) revealed that Group 3 responded significantly more to the green stimulus than either Groups 1 or 2. Again, an increase in responding to green seemed to be positively related to an increase in the number of hours of training. Figure 5, a graphic representation of relative responses to all test stimuli on Day 2 of components testing reveals a slightly different trend. Group 3 still yielded the greatest number of responses to green, but the positive linear relationship between hours of training and responses to the green component was no longer apparent. Groups 1 and 3 also showed fewer responses to the compound stimulus than Group 2. These effects were insignificant, however, as were the differences in responding to the negative components and the line-tilt components.

To examine the effects of amount of training on relative responses to the compound stimulus (S+), a one-way analysis was performed on percent of responses for each group to S+. The analysis is summarized in Table 10. No significant differences existed between the groups. Contrary to the predicted effect, amount of training produced no differences in the responses to the stimulus containing compound cues (S+). Small, insignificant differences existed between group responding to the compound-cue stimulus and all groups emitted a greater number of responses to the compound stimulus than to either element of the compound presented separately.

In order to investigate the possibility that the proportion of responses to green relative to S+ (compound stimulus) would reflect the predicted differences i.e. Groups 1 and 3 would emit a larger proportion of responses to green relative to S+, response ratios were calculated by dividing total responses to green by total responses to S+. Mean ratio values on Day 1 of testing were 13.59, 17.71 and 43.82 for each of Groups 1, 2 and 3 respectively (Figure 6). A gradual increase in number of responses to green as the number of training hours increased was again revealed. Table 11 contains the summary of the analysis performed on these ratios. A Newman-Keuls comparison of the mean ratios for each group (Table 12) indicates that Group 3 emitted a significantly larger proportion of responses to green relative to S+ than did either Groups 1 or 2. However, the ratios for Group 1 did not exceed those of Group 2. The positive relationship between responses to the colour component and hours of training was again indicated. Figure 7 graphically illustrates the mean ratio values to each test stimulus relative to S+ for all training groups on Day 2 of components testing. No significant differences between groups were obtained with these measures.

The analysis of variance performed on the relative response measures for Day 2 of components testing (Table 13) resulted in a significant Groups x Stimuli (A x B) interaction ($F=2.93$, $df=10/105$, $p<.01$). However, subsequent analyses on relative responses to green, S+ and response ratios to green relative to S+, yielded no significant results (Tables 14, 15 and 16, respectively).

Generalization Test

To test the hypothesis that Group 2 would produce the steepest generalization gradients, four two-factor analyses of variance were performed on both the absolute and relative gradients for Days 1 and 2 of testing (Tables 17 - 20). All groups produced sloped gradients, however, these analyses provided no significant Groups x Stimuli (A x B) interaction effects. Thus, no differences in the slopes of the gradients occurred on either day of testing. Examination of Figures 8, 9 and 10 reveals that Group 2 did, in fact, yield slightly sharper gradients than either Group 1 or Group 3 as was predicted. This effect, however, was not statistically significant. Figure 11 (relative gradients for Day 2 of testing) indicates that Group 1 produced the steepest gradient but these differences were also insignificant.

CHAPTER IV

Discussion

The results of the present study tend to contradict the hypotheses. Only partial support was lent to the hypothesis that groups trained for 5 or 20 hours would show greater control by colour. Group 3, which received 20 hours of training showed greater attention to colour (as measured by responses to the green component) than either Group 1 or Group 2. However, contrary to the expected results, Group 1, receiving only 5 hours of discrimination training, demonstrated least attention to the colour component. Jones (1957) suggested a perceptual attending hierarchy in which colour was higher on the hierarchy than form or position for pigeons. If attention to colour preceeds attention to line, then Group 1 should have emitted more responses to green than the other two groups. These findings indicate that discriminations based upon colour may be acquired earlier in training than expected. With a minimum of 5 hours of training, colour discriminations may become fully formed and attention to a second dimension (line) may be developing. Indications of this are contained in the response rates to the compound stimulus (S+) during components testing. Group 1's response rates to S+ were considerably higher than was predicted. In fact, no significant differences between the response rates of Group 1 and those of Groups 2 and 3 were obtained. Generalization tests revealed fairly well-developed line-tilt control in Group 1 as well. All groups produced sloped gradients and no significant differences existed in the slopes of the gradients between any of the groups. Worthy of note is the fact that during components testing relative response measures for test Day 1 revealed that a lower response rate to the compound stimulus was correlated with prolonged acquisition training. In other words, groups trained for 5, 16 and 20 hours in the discrimination evidenced a gradual decline in responses to the compound relative to increased training hours. Responses to the green component, on the other hand, were greater for Group 2 (16 hours of training) than for Group 1 (5 hours of training). Group 3, which received 20 hours of training, evidenced greater responding to green than either of the other two groups. Possibly, pigeons may initially utilize chromatic differences in the stimuli to solve a discrimination problem. However, as the birds acquire more training and experience with the discrimination, a second stimulus dimension may acquire a degree of control over responding insofar as it contributes to the total positive stimulus complex. In other words, the positive colour (green) plus the positive line-tilt (vertical) may form a gestalt to which maximum responding occurs. This statement may be borne out by the fact during components testing, little responding occurred to the vertical line alone. Generalization testing, though, seemed to be more sensitive to control by line-tilt since all groups produced peaked gradients. At this point, criticisms may be directed towards the components test in that components testing does not seem to be very sensitive to line-tilt control. However, the components test did indicate some interesting trends in the measure of responding to the green component and the compound stimulus. The results of the components test suggest that possibly that before a discrimination is well-established (20 hours of training), each component alone does not communicate the required information for the solution of the problem. At least, the utility of each dimension is not immediately apparent. Once sufficient experience with the problem is obtained, the need to attend to all aspects of the stimulus complex no longer exists. This could possibly explain why prolonged discrimination training (16-20 hours in the present study) was accompanied by an apparent decline in control of responding on the part of the compound stimulus. If a discrimination can be made quickly and efficiently utilizing only one dimension of the stimulus then there is no reason to attend to another redundant dimension. This could, perhaps, be the reason why generalization tests did not reveal differences in the slopes of the gradients. The birds in the present study were quite obviously able to use line-tilt during the discrimination however, the need to use line-tilt was decreasing. When given the opportunity to use one dimension for the sake of efficiency they will do so, as was evidenced by the response patterns during components testing. However, when colour is made irrelevant (as it is in the generaliztion test), responding to line-tilt is engaged in of necessity. Both testing procedures have their merits, though. The generalization test is a good measure of control by the line-tilt dimension. On the other hand, components tests show that attention to a second dimension of a stimulus complex may be abandoned if responding to this dimension does nothing to affect the outcome of the discrimination. In this case, the organism will rely upon an easier cue to solve the discrimination. For pigeons, colour may be an easier cue to utilize as suggested by Jones (1957) and Newman and Baron (1965).

Since Reynolds (1961), Eckerman (1967), Johnson and Cumming (1968) and Farthing and Hearst (1970) obtained uni-dimensional control of responding in their birds, the possibility exists that control by the second dimension had already been abandoned. One exception is the Farthing and Hearst study (1970). In this case, the birds received only 2.5 hours of training. With this minimum amount of training, conceivably the birds were still acquiring the initial colour discrimination. In the present study, compound stimulus control did not start to decline until more than 5 hours of training were administered. With 5 hours of training, compound stimulus control was at its maximum.

All the previously mentioned studies, though, utilized compound stimuli involving a relevant colour dimension. The second dimension (line-tilt or shape) was relevant but redundant. In view of the results of the present study, there is a possibility that in a discrimination task involving a relevant colour dimension, compound control may occur early in training. Uni-dimensional control by colour may be observed initially while the bird is still learning the discrimination. This type of control may also be observed beyond five hours of training when the discrimination is more fully formed. After the discrimination is well-established, the pigeon learns that the line-tilt or form dimension communicates no more useful information for the solution of the discrimination than the colour dimension. Thus, the bird responds to the easiest cue available.

Further evidence to show that both type of testing procedure and the type of stimuli used in the discrimination can affect the type of control evidenced during testing is contained in the Newman and Baron (1965) study. Newman and Baron (1965) employed generalization gradients as a measure of stimulus control. Only their Group 1, trained to discriminate presence-absence of a white vertical line on a green surround, yielded sloped gradients along the angularity dimension. With regard to the present results, either the type of stimuli used in the discrimination or the type of test procedure may be responsible for the type of stimulus control observed. When birds are forced to attend to a second dimension (line) as opposed to the colour dimension then stimulus control along the angularity dimension may be readily observed. This was the case in the Newman and Baron (1965) study. Group 1 produced sloped gradients for line-tilt however, line-tilt was the only relevant cue for the solution of the discrimination problem. However, when the line-tilt dimension was made redundant as in Newman and Baron's Group 2 (vertical line on green as S+, red surround as S-) flat gradients were obtained. Logically, flat gradients would occur when the line-tilt dimension was made irrelevant as in Newman and Baron's Group 4 (white vertical line on green as S+, white vertical line on red as S-). However, since Newman and Baron (1965) trained their birds for approximately 5.8 hours, it is difficult to determine why they obtained flat gradients for Group 2 trained with a redundant line-tilt dimension. Group 1 of the present study demonstrated control by the total stimulus compound as opposed to the colour dimension alone. Group 1 also showed attention to line during the generalization test. At this point, stimulus differences must be considered. The stimuli for Newman and Baron's (1965) Group 2 are most comparable to those of the present study. These birds were trained with line-tilt as a redundant cue, however, only one line-tilt (vertical) appeared in conjunction with the positive stimulus complex. A red surround only was S-. The present study, though, employed two line-tilts. A vertical line was contained in the positive stimulus while a horizontal line was contained in the negative stimulus complex. Possibly, this form of training contributed to greater discriminability of the redundant line-tilt dimension. Although line-tilt was redundant and responses to the compound containing the line decreased as training was increased, training with vertical positive and horizontal negative may have enabled the bird to discriminate angular orientation as well as colour. Newman and Baron's Group 2 had no basis for comparison with respect to line-tilt. Experience with a vertical line only was acquired. Logically, for these birds, any line on a green surround could represent the positive stimulus. Consequently, flat gradients would be obtained. Orientation is often ignored by human children. In a perceptual learning task (Pick, 1965) when children are required to match comparison stimuli with a given standard, it has been found that children identify the features of the standard stimulus with no regard to rotations and transformations. In other words, if a comparison stimulus matches the standard with respect to features or general characteristics, then children will label it to be the same as the standard even if it is rotated 180°. When they were taught that only one orientation was acceptable, the children consistently chose the correct comparison stimuli. Similarly, birds may respond to all line orientations until they are taught that only one orientation (vertical) represents the positive stimulus.

The present study attempted to delineate the relationship between hours of training and the type of stimulus control observable following varied lengths of training. There is an apparent relationship between length of training, type of stimulus used in the discrimination training and the type of test procedure used to measure stimulus control. Further study is suggested to define the interactions between these variables.

APPENDIX A

Order of Presentation of S+ and S-

During Discrimination Training

Order of Presentation of S+ and S-

During Discrimination Training

1.	S+	31.	S+
2.	S-	32.	S-
3.	S-	33.	S+
4.	S+	34.	S-
5.	S-	35.	S-
6.	S+	36.	S+
7.	S+	37.	S-
8.	S-	38.	S+
9.	S+	39.	S+
10.	S-	40.	S-
11.	S-	41.	S+
12.	S+	42.	S-
13.	S-	43.	S-
14.	S+	44.	S+
15.	S+	45.	S-
16.	S-	46.	S+
17.	S+	47.	S+
18.	S-	48.	S-
19.	S-	49.	S+
20.	S+	50.	S-
21.	S-	51.	S-
22.	S+	52.	S+
23.	S+	53.	S-
24.	S-	54.	S+
25.	S+	55.	S+
26.	S-	56.	S-
27.	S-	57.	S+
28.	S+	58.	S-
29.	S-	59.	S-
30.	S+	60.	S+

APPENDIX B

Responses During Discrimination Training

Responses During Discrimination Training

Group	S#	Stimulus	Days 1	2	3	4	5
1	196	S+	2885	2683	2281	1937	1757
		S-	26	0	0	0	2
1	19	S+	1271	2022	2078	1873	2297
		S-	12	13	8	3	6
1	2061	S+	1883	1793	1590	1414	1154
		S-	21	7	46	259	796
1	287	S+	1917	1716	1622	1529	1615
		S-	10	0	0	0	10
1	4795	S+	2091	1257	1242	1020	1000
		S-	2	0	4	2	0
1	285	S+	1806	1070	988	1084	985
		S-	32	1	0	1	2
1	2032	S+	648	861	1020	1000	921
		S-	0	0	0	0	0
1	241	S+	1825	1652	2022	1777	1501
		S-	235	43	74	99	35

Responses During Discrimination Training

Group	S#	Stimulus	Days 1	2	3	4	5	6	7	8	9	10
2	132	S+	1870	1876	2039	2077	1936	1902	1906	1754	1661	1693
		S-	50	3	2	4	0	0	4	0	1	1
2	2407	S+	1961	2562	2620	2768	3098	3490	3849	3366	3297	3146
		S-	234	1	0	13	10	12	60	7	4	2
2	2033	S+	2209	1899	2383	2360	1968	1931	2108	2333	2359	2370
		S-	42	0	0	0	0	3	0	0	0	4
2	4773	S+	1470	1344	1512	1712	1667	1332	1175	1509	1645	1542
		S-	76	1	0	1	0	2	0	5	0	0
2	1675	S+	1086	1636	4656	4677	5734	6412	5854	6389	6858	6097
		S-	3	0	1	0	0	0	47	106	2	9
2	4754	S+	1051	1596	1843	1629	1405	1570	1630	1635	1584	1655
		S-	0	36	2	1	4	0	0	1	0	2
2	2049	S+	1828	1712	2033	2292	2226	2358	2736	2993	3225	3793
		S-	8	0	1	2	6	2	0	0	0	0
2	2044	S+	1650	2050	2409	2559	2788	2649	2973	3251	2300	1788
		S-	23	0	0	4	1	3	0	0	3	7

Responses During Discrimination Training (Cont'd)

Group	S#	Stimulus	Days 11	12	13	14	15	16
2	132	S+	1588	1397	1362	1308	1439	1605
		S-	0	1	0	0	1	5
2	2407	S+	2779	2422	1825	1603	1934	1765
		S-	8	7	6	4	0	0
2	2033	S+	2379	2355	2612	2590	2674	2802
		S-	6	5	0	3	2	2
2	4773	S+	1986	1882	1967	2205	2371	2437
		S-	0	0	0	0	0	2
2	1676	S+	6284	7064	6488	7181	7225	6120
		S-	2	63	250	40	49	2
2	4754	S+	1586	2074	2194	2254	2108	2273
		S-	1	3	3	7	2	0
2	2049	S+	3638	3619	3640	3620	3696	3798
		S-	0	0	0	0	0	0
2	2044	S+	1623	1656	1507	1396	1523	1828
		S-	6	2	1	3	3	2

Responses During Discrimination Training

Group	S#	Stimulus	Days 1	2	3	4	5	6	7	8	9	10
3	70	S+	1034	1396	2207	2647	2671	2407	2681	2156	2647	2689
		S-	13	0	0	0	1	0	0	0	0	0
3	208	S+	2143	2567	2833	2978	3024	3095	3810	4079	4713	4567
		S-	30	0	4	3	2	1	0	0	0	0
3	1660	S+	1783	1773	1463	1348	1202	1497	1335	1220	1145	1040
		S-	25	6	1	4	0	2	2	2	0	0
3	1639	S+	1339	1165	1093	975	1448	1572	1273	979	1347	1415
		S-	43	0	0	0	5	0	0	0	0	0
3	1018	S+	1812	1932	1961	1847	1638	1704	2133	2297	2358	2202
		S-	2	4	0	1	1	2	0	5	0	1
3	2054	S+	1979	1677	1305	1529	1865	1447	1401	1666	1514	1557
		S-	6	3	0	2	1	0	0	0	0	0
3	225	S+	964	767	712	1074	1191	1465	1194	1285	1530	1481
		S-	25	8	2	13	4	3	3	0	1	0
3	2056	S+	931	1418	1464	1512	1811	1745	1612	1597	1537	1513
		S-	13	4	0	0	0	0	0	0	0	0

Responses During Discrimination Training (Cont'd)

Group	S#	Stimulus	Days 11	12	13	14	15	16	17	18	19	20
3	70	S+	3301	3206	3058	2902	3374	3975	4036	3456	3238	2718
		S-	0	1	0	0	0	0	0	0	0	2
3	208	S+	4875	5521	5669	5697	6470	5643	5859	4838	4883	5573
		S-	0	11	6	4	4	3	2	1	1	0
3	1660	S+	1046	1021	1141	998	1182	957	1123	1264	1187	1269
		S-	1	0	0	2	0	0	2	1	0	0
3	1639	S+	1144	1289	1186	1254	1588	1708	1482	1499	1723	1991
		S-	0	0	0	0	0	0	0	0	0	0
3	1018	S+	2130	2136	2086	2277	2286	2348	2139	2078	1898	1844
		S-	0	0	0	0	0	0	0	1	0	0
3	2054	S+	1851	1533	1474	1772	1587	1425	1748	2098	2399	2192
		S-	0	0	0	0	0	0	0	0	0	0
3	225	S+	1478	1528	1293	1511	1388	1517	1319	1280	1500	1559
		S-	2	5	8	7	1	5	0	2	0	0
3	2056	S+	1598	1678	1495	1412	1460	1395	1325	1147	1197	1546
		S-	0	137	123	133	110	114	368	12	16	31

APPENDIX C

Order of Presentation of Stimuli

During Components Test

Order of Presentation of Stimuli

During Components Test

1. Red
2. Vertical
3. Horizontal
4. Green
5. S−
6. S+
7. Horizontal
8. S−
9. Vertical
10. S+
11. Red
12. Green
13. Green
14. S+
15. S−
16. Red
17. Vertical
18. Horizontal
19. Green
20. Red
21. Horizontal
22. S+
23. Vertical
24. S−
25. Vertical
26. Red
27. S−
28. Horizontal
29. S+
30. Green
31. Red
32. S+
33. Vertical
34. Horizontal
35. Green
36. S−
37. Horizontal
38. S+
39. Green
40. Vertical
41. Red
42. S−
43. Vertical
44. S+
45. S−
46. Red
47. Green
48. Horizontal

APPENDIX D

Responses to Stimuli During Components Testing for Test Day One

Responses to Stimuli During Components Testing

for Test Day One

Group	S#	Red	Green	Vertical	Horizontal	S+	S-
1	196	0	38	3	1	373	0
1	19	7	28	9	0	695	1
1	2061	9	12	12	1	215	6
1	287	0	6	3	0	333	0
1	4795	0	169	0	0	333	0
1	285	0	40	2	0	278	0
1	2032	0	5	1	1	302	9
1	241	0	84	13	0	411	0
TOTALS		16	382	43	3	2940	16
MEANS		2.00	47.75	5.37	.37	367.50	2.00

Responses to Stimuli During Components Testing

for Test Day One

Group	S#	Red	Green	Vertical	Horizontal	S+	S-
2	132	0	164	27	0	514	0
2	2407	14	86	11	3	580	0
2	2033	0	185	9	0	342	0
2	4773	0	47	1	0	561	0
2	1675	2	130	32	0	1158	0
2	4754	0	37	10	1	544	0
2	2049	0	34	0	0	377	0
2	2044	8	26	3	0	475	0
TOTALS		24	709	93	4	4551	0
MEANS		3.00	88.62	11.62	.50	568.87	0

Responses to Stimuli During Components Testing

for Test Day One

Group	S#	Red	Green	Vertical	Horizontal	S+	S-
3	70	0	138	6	0	494	0
3	208	0	29	0	0	806	0
3	1660	0	117	0	0	204	0
3	1639	0	243	0	0	267	0
3	1018	0	387	1	0	491	0
3	2054	0	35	13	0	498	0
3	225	0	95	5	1	307	0
3	2056	19	224	13	1	415	2
TOTALS		19	1268	38	2	3482	2
MEANS		2.37	158.50	4.75	.25	435.25	.25

APPENDIX E

Responses to Stimuli During Components Testing

for Test Day Two

Responses to Stimuli During Components Testing

for Test Day Two

Group	S#	Red	Green	Vertical	Horizontal	S+	S-
1	196	5	32	0	0	544	0
1	19	0	2	0	0	556	1
1	2061	5	1	0	1	326	25
1	287	0	0	0	0	378	4
1	4795	1	54	1	0	317	0
1	285	0	3	0	0	369	0
1	2032	0	0	1	0	136	1
1	241	2	7	1	0	389	9
TOTALS		13	99	3	1	3015	40
MEANS		1.62	12.37	.37	.12	376.87	5.00

Responses to Stimuli During Components Testing

for Test Day Two

Group	S#	Red	Green	Vertical	Horizontal	S+	S-
2	132	26	0	0	0	318	3
2	2407	8	4	0	8	413	10
2	2033	0	26	1	0	364	0
2	4773	0	11	0	1	343	0
2	1675	1	5	5	0	1011	0
2	4754	7	1	0	0	304	0
2	2049	0	0	0	0	441	0
2	2044	2	4	0	0	387	0
TOTALS		44	51	6	9	3581	13
MEANS		5.50	6.37	.75	1.12	447.62	1.62

Responses to Stimuli During Components Testing

for Test Day Two

Group	S#	Red	Green	Vertical	Horizontal	S+	S-
3	70	0	5	0	0	348	0
3	208	2	5	0	0	58	1
3	1660	14	76	0	0	271	0
3	1639	0	22	0	0	133	0
3	1018	0	101	0	0	416	0
3	2054	0	0	0	0	439	0
3	225	3	6	1	5	336	3
3	2056	5	13	11	0	388	8
TOTALS		24	228	12	5	2389	12
MEANS		3.00	28.50	1.50	.62	298.62	1.50

APPENDIX F

Order of Presentation of Stimuli During Generalization Test

Order of Presentation of Stimuli

During Generalization Test

1. 22.5° left
2. 0°
3. 22.5° right
4. 45.0° left
5. 45.0° right
6. 0°
7. 45.0° left
8. 22.5° left
9. 22.5° right
10. 45.0° right
11. 22.5° right
12. 22.5° left
13. 45.0° left
14. 0°
15. 45.0° right
16. 45.0° left
17. 22.5° right
18. 0°
19. 22.5° left
20. 45.0° right
21. 22.5° left
22. 0°
23. 22.5° right
24. 45.0° left
25. 45.0° right
26. 0°
27. 45.0° left
28. 22.5° left
29. 22.5° right
30. 45.0° right
31. 22.5° right
32. 22.5° left
33. 45.0° left
34. 0°
35. 45.0° right
36. 45.0° left
37. 22.5° right
38. 0°
39. 22.5° left
40. 45.0° right
41. 22.5° right
42. 22.5° left
43. 45.0° left
44. 0°
45. 45.0° right
46. 45.0° left
47. 22.5° right
48. 0°
49. 22.5° left
50. 45.0° right

APPENDIX G

Responses to Stimuli During Generalization Testing

for Test Day One

Responses to Stimuli During Generalization Testing

for Test Day One

Group	S#	45°L	22.5°L	0°	22.5°R	45°R
1	196	81	183	339	253	69
1	19	56	152	335	41	27
1	2061	204	140	175	74	46
1	287	50	124	73	22	5
1	4795	55	32	61	24	25
1	285	12	79	89	25	6
1	2032	0	15	46	2	1
1	241	8	76	81	147	7
TOTALS		466	801	1199	588	186
MEANS		58.25	100.12	149.87	73.58	23.25

Responses to Stimuli During Generalization Testing

for Test Day One

Group	S#	45°L	22.5°L	0°	22.5°R	45°R
2	132	6	67	68	42	2
2	2407	99	228	280	242	63
2	2033	102	198	192	130	38
2	4773	45	107	217	111	10
2	1675	41	287	590	97	160
2	4754	25	99	57	63	20
2	2049	3	16	271	22	11
2	2044	8	71	118	53	4
TOTALS		329	1073	1793	760	308
MEANS		41.12	134.12	224.12	95.00	38.50

Responses to Stimuli During Generalization Testing

for Test Day One

Group	S#	45°L	22.5°L	0°	22.5°R	45°R
3	70	31	175	119	23	1
3	208	4	40	21	8	3
3	1660	36	67	69	28	6
3	1639	21	77	70	57	13
3	1018	54	78	114	105	61
3	2054	8	72	421	179	2
3	225	67	63	62	53	58
3	2056	31	96	315	140	24
TOTALS		252	668	1191	593	168
MEANS		31.50	83.50	148.87	74.12	21.00

APPENDIX H

Responses to Stimuli During Generalization Testing

for Test Day Two

Responses to Stimuli During Generalization Testing
for Test Day Two

Group	S#	45°L	22.5°L	0°	22.5°R	45°R
1	196	24	72	161	100	17
1	19	1	10	198	3	1
1	2061	23	31	82	15	20
1	287	1	94	83	2	4
1	4795	1	13	45	15	1
1	285	9	16	78	0	3
1	2032	6	5	35	2	2
1	241	0	29	79	47	8
TOTALS		65	270	761	184	56
MEANS		8.12	33.75	95.12	23.00	7.00

Responses to Stimuli During Generalization Testing
for Test Day Two

Group	S#	45°L	22.5°L	0°	22.5°R	45°R
2	132	2	39	93	4	8
2	2407	24	163	219	55	4
2	2033	31	149	238	186	16
2	4773	2	49	45	4	14
2	1675	4	32	863	28	2
2	4754	4	38	14	9	11
2	2049	1	6	71	34	0
2	2044	0	15	114	23	9
TOTALS		68	491	1657	343	64
MEANS		8.50	61.37	207.12	42.87	8.00

Responses to Stimuli During Generalization Testing
for Test Day Two

Group	S#	45°L	22.5°L	0°	22.5°R	45°R
3	70	9	50	116	7	0
3	208	4	7	0	0	0
3	1660	15	62	60	10	0
3	1639	4	120	111	23	7
3	1018	3	31	58	52	10
3	2054	0	7	245	29	0
3	225	19	32	20	22	14
3	2056	3	65	270	65	0
TOTALS		57	374	880	208	31
MEANS		7.12	46.75	110.00	26.00	3.87

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